INPUT AND OUTPUT DEVICES FOR ELECTRONIC DIGITAL CALCULATING MACHINERY

Samuel N. Alexander

LEADER OF COMPUTER COMPONENTS GROUP, NATIONAL BUREAU OF STANDARDS

The design of input and output devices for electronic digital computers poses a specialized problem in electrical communications. Information sent in from the outside tells the machine how to solve the problem and also supplies it with the requisite initial data. Naturally, this information needs to be converted into a form that can be interpreted by the machine. Conversely, solutions prepared within the machine must be translated into a form that is readily interpreted by the users of the machine. These are the two main tasks allotted to the input and output devices of electronic calculating machinery.

All the electronic digital computers now planned will use coded groups of electrical pulses for the representation of information within the machine. Moreover, the coding will employ some forms of the binary scheme of notation. It happens that modern printing telegraph equipment uses a code that is binary in character. Thus it was quite natural to borrow from this highly developed communication art for the initial development of input and output devices for conveying information into and out of electronic digital computers.

The requirement that these devices provide "error-free" transfer of information into and out of the computing machine leads to several significant modifications of the techniques ordinarily used in printing telegraphy. These modifications are effected through the use of strategically located checking and correcting equipment. The nature and extent of these functions are best described along with the equipment itself.

In the initial development work at the Bureau of Standards, equipment manufactured by the Teletype Corporation is being used. This choice was made simply because this gear was readily obtainable from other governmental activities and its performance was known to be adequate for the present program. We recognize that devices designed by modifying and adding to available equipment may not yield all the operating features that are desired. However, we do believe that the devices being developed will meet the needs of the immediate future. Moreover, the experience gained from their design and use is expected to lead to standards for the development of equipment specifically suited to the task.

The end product of the proposed input system being assembled by the Bureau is a perforated tape that contains both the program for the problem and its initial data. This information appears as a sequence of characters, each of which contains five binary elements, the individual elements being designated by the presence or absence of a perforation in the tape. The information can be coded in several ways, but digression into this topic is not feasible in a brief discussion of the input device.

While the perforated tape might be used for loading the computing machine, something on the order of photoelectric scanning technique would be needed to attain acceptable speeds. For this reason, a binary coded medium such as movie film or magnetic wire appears better suited to the task of rapidly loading the computer. This transfer from a perforated tape to an alternate binary medium can be resolved into a reliable automatic procedure. Present plans are to provide, along with the input device, auxiliary equipment for accomplishing the transfer to magnetic wire.

At this point, it would appear that preparing perforated tape has introduced an unnecessary

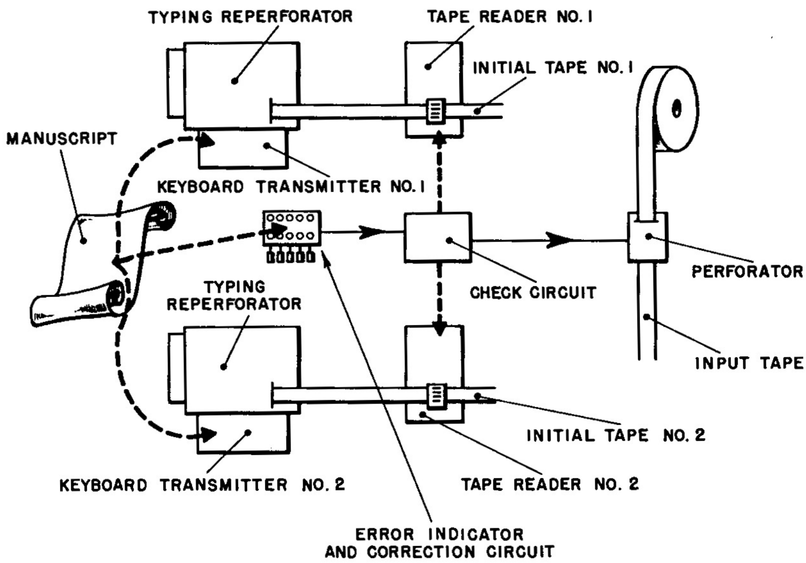

Figure 1

step. However, there are practical considerations to recommend this extra step. The tapes are easy to prepare, convenient to check for errors, and readily spliced to insert corrections and additions. Moreover, the tape serves as a master record in the event of damage to the magnetic wire. The ease of checking is the most significant of these features, particularly since it leads to a checking procedure that can be arranged to minimize dependence upon operator alertness and faultless performance of equipment.

We are investigating two approaches to the problem of checking. The one shown in Fig. 1 is called the parallel method of checking. Independent versions of the manuscript are transcribed by two operators working at keyboard transmitters #1 and #2, respectively. These versions are prepared in the form of initial tapes #1 and #2 by the typing reperforators, which perforate the tapes and also type the corresponding characters onto the tape for simple proofing. Errors arising from either of the operators or from the equipment are detected by automatic electrical comparison. For this purpose the initial tapes pass through tape readers #1 and

#2, and the electrical sensings of the two tapes are compared by the check circuit. Whenever the check circuit finds a coincidence, the sensings are allowed to set the perforator, which in turn prepares the input tape for the computer. The coincidence also initiates the advance of both initial tapes in their readers.

This procedure repeats automatically until such time as the check circuit detects a non-coincidence. When a non-coincidence occurs, the system "locks out," and none of the above actions can occur. The attention of an attendant is now necessary to resolve the difficulty. The first step is to ascertain whether the "lock out" is the result of malfunctioning of the checking system, or is due to a discrepancy between the input tapes. If it is the latter, the manuscript is consulted to determine the proper character for the input tape. The attendant sets this character in the correction circuit and this action circumvents the checking circuit by providing an artificial coincidence. The electrical sensing, corresponding to the correct character, sets the perforator and the coincidence actuates it. The coincidence can also be used to initiate the advance of both initial tapes to the next characters. Following this action the correction circuit is automatically disconnected, and the system returns to the normal checking condition.

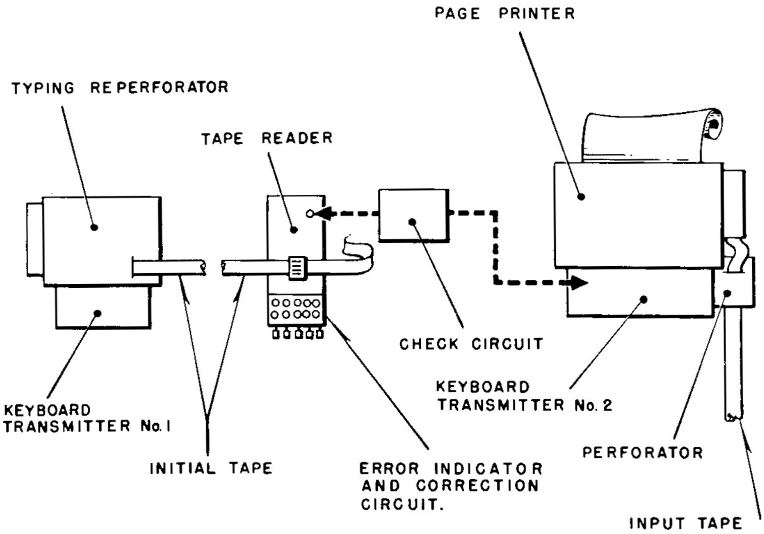

Figure 2

The second approach to the checking problem is termed the cascade method of checking and is shown in Fig. 2. As before, two operators are used, and the task of the first operator, working at keyboard transmitter #1, is the same as for either operator in the parallel method. On the other hand, the second operator, working at keyboard transmitter #2, prepares the input tape directly and at the same time produces page proof of its contents. The initial tape provides a character by character check on the second operator's transcription *prior* to the perforation of the character into the input tape.

Checking is obtained through the use of a set of five switches added to the keyboard perforator assembly. These switches provide an electrical sensing corresponding to the key being pressed. This sensing is automatically compared by the check circuit with the corresponding sensing of the initial tape by the tape reader. Each coincidence initiates the perforating and typing operations, and also advances the initial tape to the next character. A non-coincidence "locks out" the system and calls the operator's attention to the disagreement.

The second operator resolves the difficulty by careful reference to the manuscript. If the error is due to the second operator, she merely strikes the proper key. If the error is in the initial tape, the proper character must be inserted into the correction circuit. Now striking the correct key provides the coincidence needed to initiate the perforation and typing operations. As in the parallel scheme, the coincidence can also be used to initiate the advance of the initial tape to the next character. Finally, the correction circuit is automatically disconnected, and the system returns to the normal checking condition.

In both the parallel and cascade systems of checking, it is possible to pass through the coincident type of error. It is to reduce the probability of the occurrence of such errors that separate operators and separate transcribing machines are used in arriving at the input tape. In this respect the cascade scheme is slightly better, since each transcribing machine is of different construction and design. The cascade scheme is also favored by the directness of its operation and the fact that page proof is conveniently available for the detection of coincident errors. However, since the parallel system is relatively easy to set up, it is planned to try out each method before a final choice is made.

In common with the input device, the output device provides a reliable means for transferring the information from its initial medium onto a perforated tape. This final tape serves as a master record from which typed copies can conveniently be prepared on a page printer whenever desired. The output device could be designed to actuate the page printer directly, but the additional step of tape preparation can be justified in terms of practical consideration and convenience.

For the present, the results from the calculating machine will appear in the form of binary information on magnetized wire. The basic features of an output device which will transfer the results from the wire to a perforated tape are shown in Fig. 3. The information flows from the magnetized wire down to the decade ring and into either register #1 or #2. The electronic commutator controls the transfer from the registers into the teletype perforator, which in turn prepares the final tape.

The incoming electrical signals, generated by the motion of the wire, always have two parts of opposite signs. Thus a negative magnetic signal on the wire corresponds to an electrical signal that has its minus part preceding the plus. For a positive magnetic signal, the sequence is reversed, and the leading portion is plus and the trailing portion minus. In Fig. 3 these are denoted by "a" and "b" on the signal shown at the amplifier output.

This signal is used by the pulse shaper and sorter to provide two sets of output pulses. At one output there appears a pair of pulses of like sign. These pulses correspond in time to "a"

and "b," and are used to energize the binary counter. The binary counter also has a pair of outputs, one of which emits a single pulse corresponding to "b" only. This pulse goes to the input bus of the decade ring counter.

The other set of signals put out by the pulse shaper and the binary counter is used to control the two grids of the main gate tube. The signal from the binary counter has a wave form that allows only the "a" pulse in the signal from the pulse shaper to appear in the plate

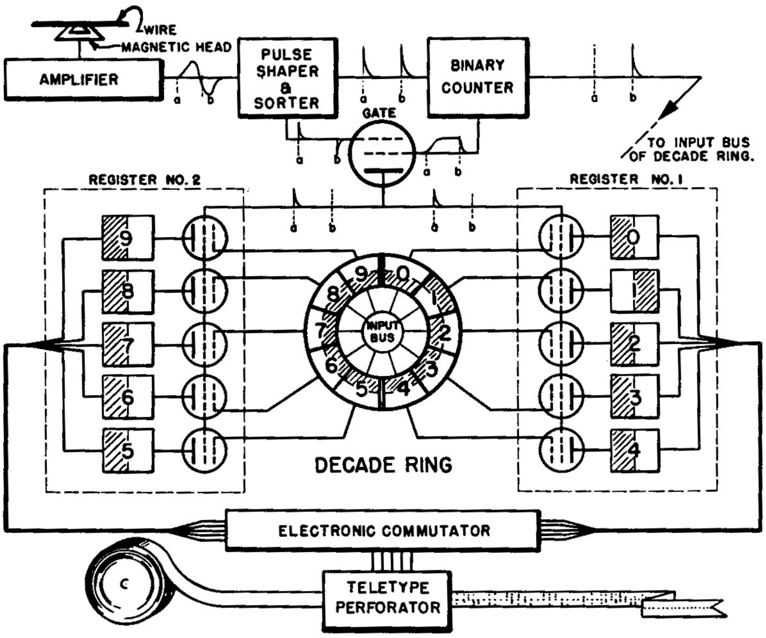

Figure 3

circuit of the gate tube. This "a" pulse, which carries through the system information on the polarity of the original magnetic signal, energizes one of the grids of each gating tube in registers #1 and #2.

Each gating tube controls the entry of the "a" pulses into the electronic register units. These register units, which are indicated by the numbered boxes in Fig. 3, are the means of storing temporarily the information carried by the "a" pulse. The specific destination of an individual "a" pulse is determined by the fact that only one of the ten gating tubes has both grids energized. The control signal for the second grid is provided by the decade ring, in accordance with the particular stage to which it is set at that moment. Fig. 3 shows the decade ring at stage #1 and register unit #1 set to correspond to the sign of the incoming "a" pulse.

The counting ring advances one stage for each magnetic signal and causes the sequential distribution of the "a" pulse into the registers to keep in step with the ring. The setting up of register #1 is completed just as the decade ring advances from stage #4 to #5. At this

point the ring signals register #2 to clear, thus preparing it to accept the next sequence of five "a" pulses. The electronic commutator, meanwhile, connects register #1 to the teletype perforator, which transfers the information from the register to the final tape. The operation is repeated as the ring advances from stage #9 to #0. Thus, one character is always being assembled while the preceding one is being perforated into the tape.

Several desirable operating features are achieved by arranging the output device in this particular way. First, the system inherently keeps in step with the information carried by the magnetic wire. This condition obtains regardless of irregularities in signal spacing on the wire or nonuniform motion of the wire. The use of the two registers effectively couples the essentially uniform flow of information from the wire to the intermittent flow to the perforated tape. The tempo of the entire system is determined by its slowest element, the teletype perforator. By using two registers, the allowable operating rate is increased fivefold over that of a system using but one register. It is believed that these advantages justify the increased complexity of the proposed output device.